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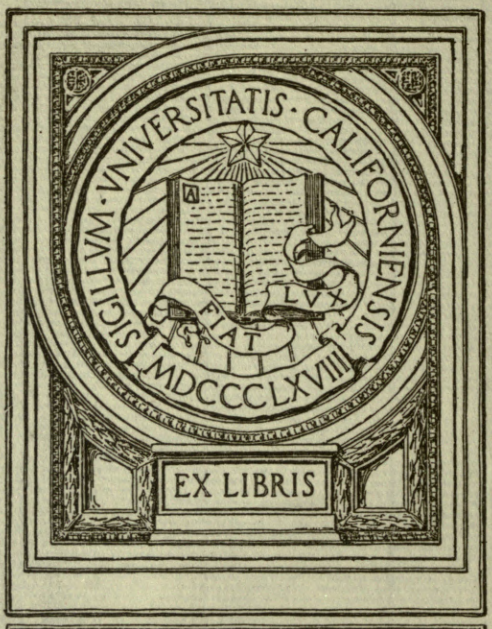

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The Westinghouse-Leblanc Condenser

A description with
suggestions and instructions
for its

INSTALLATION CARE AND OPERATION

HUNT, ROCK & CO., INC.
ENGINEERS
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Instruction Book, WM102—Second Edition August, 1910

The Westinghouse Machine Company

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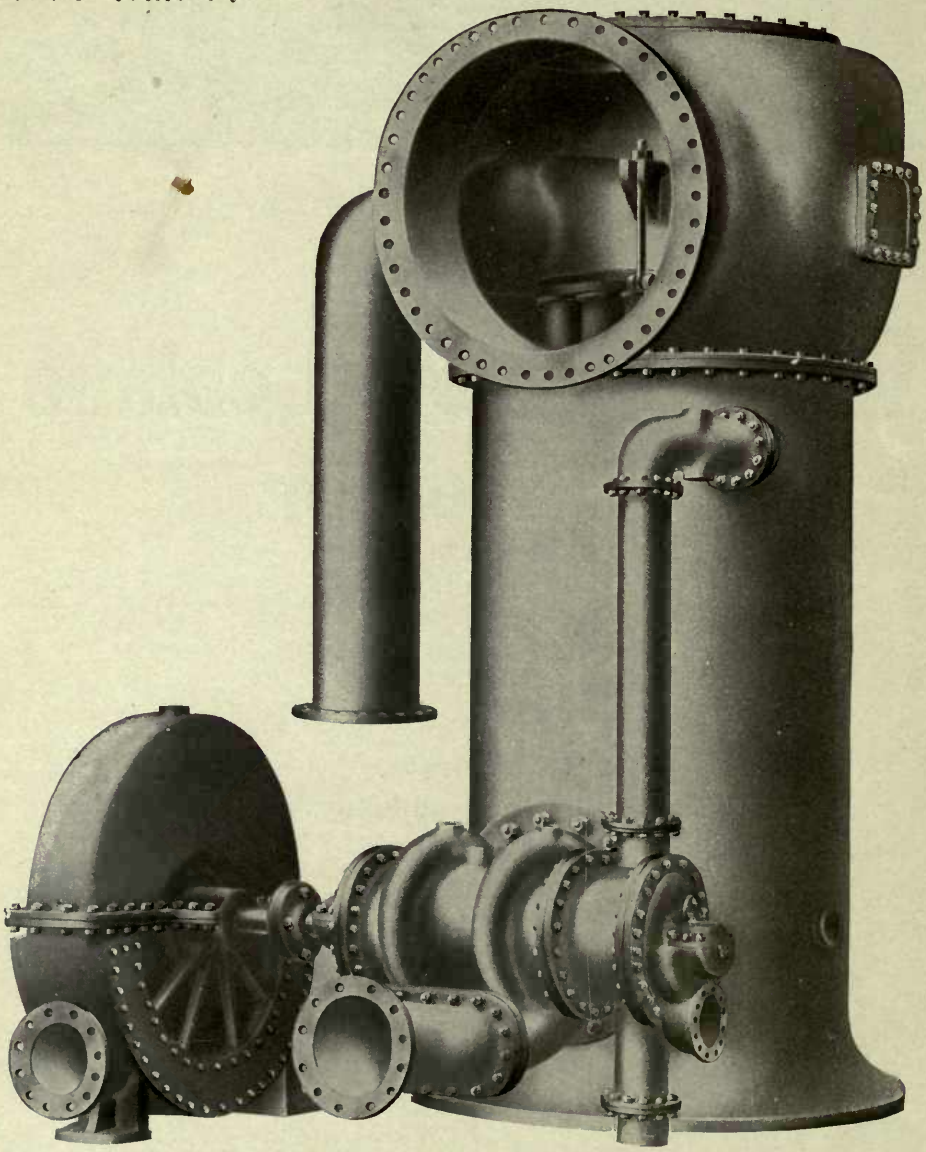

WESTINGHOUSE-LEBLANC CONDENSER WITH STEAM TURBINE DRIVE

R. M. D.

THE WESTINGHOUSE-LEBLANC CONDENSER

The Westinghouse-Leblanc Condenser represents the highest development of that class of condensing apparatus known as the jet type. In most phases of modern engineering a radical improvement in economy or efficiency is attained by increased complication or addition of parts. In the case of the Leblanc condenser the improvement in efficiency has been attained in a less complicated machine.

There are no rubbing parts except the bearings and packing glands. There are no reciprocating parts, no valves in the pumps, nor are there any parts requiring lubrication other than the bearings.

The Prime Advantages of the Leblanc Condenser are:

1. The striking simplicity of the apparatus, and consequent ease of manipulation and operation.
2. The extraordinary efficiency as compared with other types of jet condensers.
3. The absence of internal rubbing parts, so that wear is eliminated, and consequently the efficiency does not drop off after long periods of operation.
4. The concentration of all of the moving parts of the apparatus on a single revolving shaft
5. The adaptability for direct driving by a steam turbine or electric motor—either of which represents the utmost possibilities in the way of simplicity and reliability.

General Description

Figure 1 shows a sectional view of a condenser. In general it consists of a chamber with means for admitting the steam and water, and intimately mixing them. The condensed steam and water are then discharged by means of a properly designed centrifugal pump. The air not entrained with the water is taken off by a special turbine air pump.

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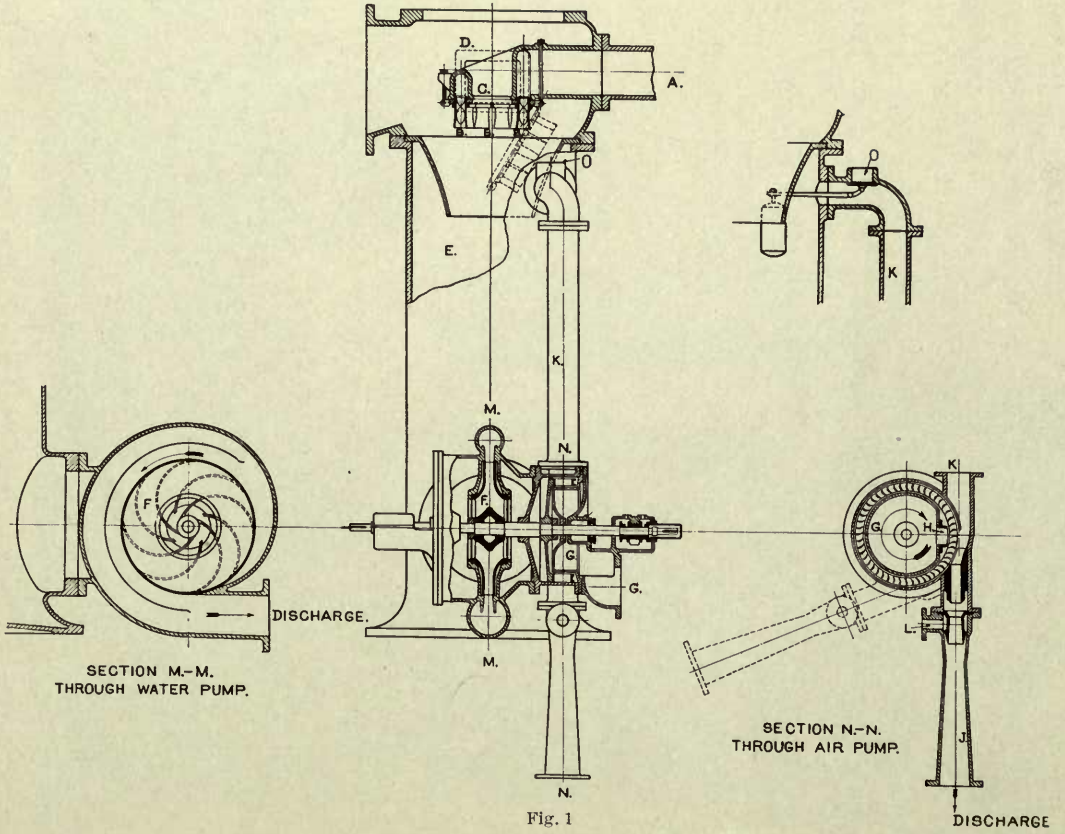


Fig. 1

SECTIONAL VIEWS OF CONDENSER, AND AIR AND WATER PUMPS

Referring to the illustration, the injection water enters at A, by virtue of the vacuum within the condenser, and is drawn through the induction passages B-B-B.

It then meets and is intimately mixed with the exhaust steam, which has entered either at the top or side inlet on the condenser head. The mixture of condensed steam and water drops through the large combining cone into the chamber E, and is discharged by the centrifugal pump F. If desired, this pump can be proportioned to deliver the hot water to the top of a cooling tower or through spray nozzles, or against any pressure such that the head imposed, including friction, is not more than 50 feet above the condenser base.

It will be noted that the nozzle plate C, can be swung into the position shown in dotted lines so that any debris that may have lodged there can be cleaned out. Access to this plate may be had through manholes on the side of the top chamber.

These nozzles have liberal passages, and if proper screens or strainers are placed in the water intake it should not be necessary to clean them.

The air pump draws its air through the pipe K. Note the sectional view of the air pump to the right in Figure 1. To start the air pump in operation high pressure steam is turned into the connection L. The cone near L forms the annular nozzle of a steam ejector, so that on opening the valve in the steam line to L, a vacuum is created in the body of the air pump. The chamber G being piped up to a source of water supply is immediately filled on account of the vacuum created by the steam ejector. Water then flows through the distributing nozzle H, and is projected in layers in a downward direction through the combining passages into the diffuser J. Between the successive layers of water, layers of air are imprisoned, these layers of water (on account of the high peripheral speed of the turbine wheel which throws them downwards) have a velocity sufficient to enable them to overcome the pressure of the atmosphere and force their way out of the pump in which a high vacuum exists. The layers of water act like a succession of water pistons with large volumes of air between them.

In the elbow on the top of the pipe K, there is a valve controlled by a copper float on the inside of the condenser

chamber. Should the water for any reason rise as high as the float this valve will open and by admitting air, lower the vacuum so that no more water will be drawn into the condenser.

This vacuum breaker is placed on the condenser for unforseen emergencies only, as for example, the accidental shutting down of the pump by an inexperienced attendant, etc. In general this arrangement will prevent flooding of the condenser for any external cause whatsoever.

The vacuum breaker float is so situated that under usual operating conditions it is never in contact with the water. It is immersed only in emergencies such as have just been mentioned.

Just above the copper float is the condenser cone, see Fig. 1, which acts like a hood and shields it from the erosive action of the water. The float is therefore a wholly reliable piece of apparatus, its movements are positive, and its action certain.

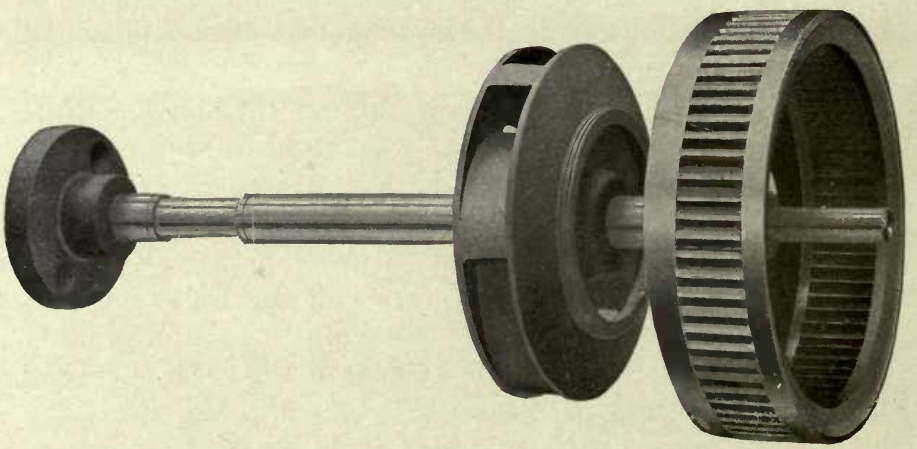


Fig. 2
MOVING PARTS OF WESTINGHOUSE-LEBLANC CONDENSER

Figure 2 shows all of the moving parts of the Leblanc condenser. Both parts, the centrifugal and air pump rotors, are on a common shaft, making a construction that in point of simplicity is absolutely elemental.

In case of salt water or impure water full of chemical matter, the pump runners are made of bronze and the shaft also thereby thoroughly protecting the pump from any corrosive action.

Installation of the Westinghouse-Leblanc Condenser

The condenser is constructed with both a side and a top inlet for the admission of steam. A blank flange is supplied so that the unused inlet may be closed off.

The condenser is preferably installed with the steam entering the side. This arrangement usually works out to the best advantage, as it adapts itself excellently to the most desirable power plant layouts.

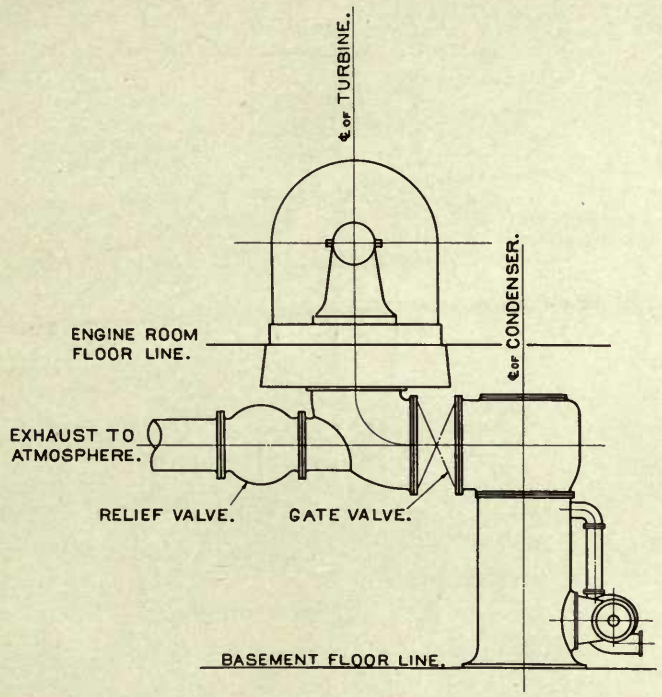


Fig. 3

SHOWING EXHAUST CONNECTED TO SIDE INLET

In Figure 3, it will be noted that when installed so that the steam enters at the side inlet, the condenser is thoroughly accessible. By having a trap door in the engine room floor the erection can be carried on by means of the engine room crane, and any part of the condenser can be disassembled by the same means if it should ever be necessary to do so.

Figure 4 represents an arrangement in which the condenser is located beneath the turbine, steam entering through

the top inlet. This is an excellent arrangement but requires greater vertical height to accommodate the condenser, and, of course, makes the erection work more difficult. The condenser must always be in place before the turbine can be erected.

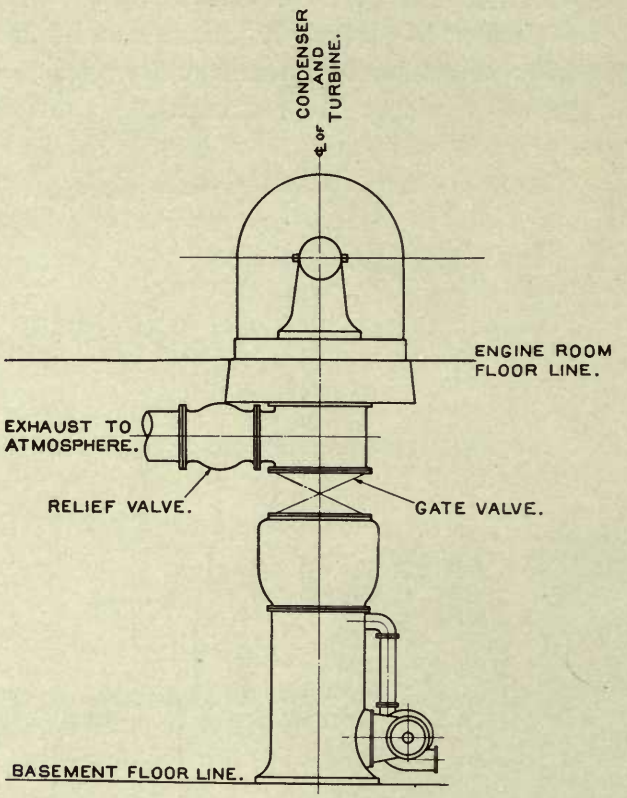


Fig. 4

SHOWING EXHAUST CONNECTED TO TOP INLET

It is not as accessible as in the arrangement shown in Figure 3, and in case it were necessary to make a repair (say for example, on the expansion joint between the turbine and the condenser), it would be practically necessary to lift the turbine off its foundation to remove this expansion joint.

Location of Hot and Cold Wells

The usual and most convenient arrangement is that shown in Figs. 5 and 6. The cold well should be located as close as possible to the condenser, and in no case should it have

to lift the injection water more than 18 feet, as indicated in Fig. 5. In case the cold well is considerably distant from the condenser, the lift should be made still less as the piping will offer a certain amount of resistance to the flow of the water.

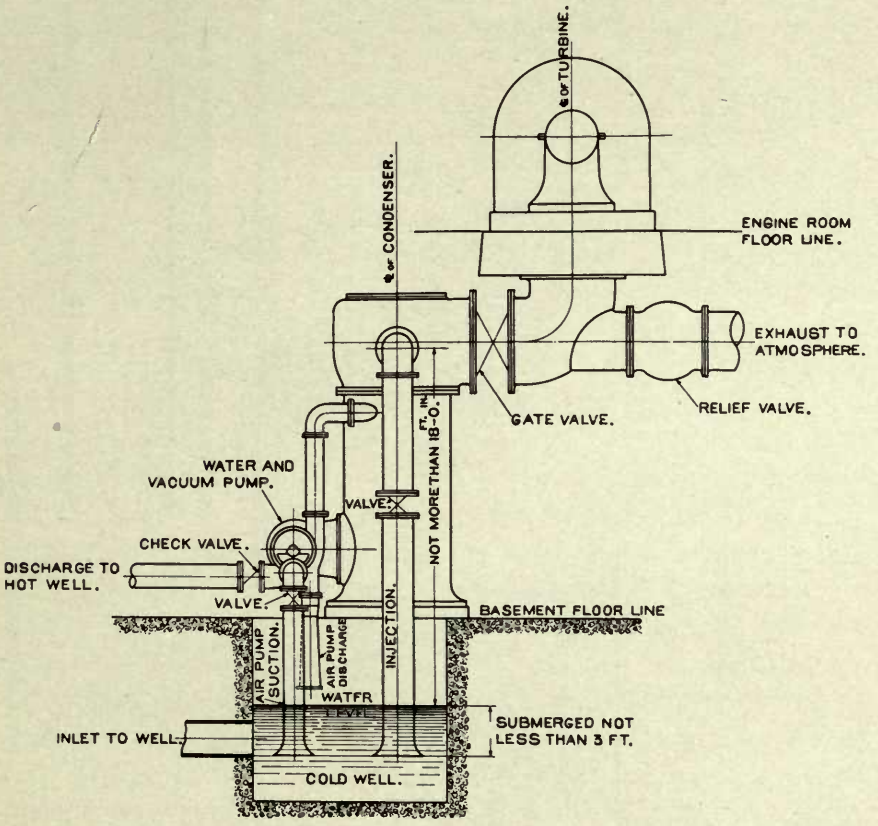


Fig. 5

GENERAL ARRANGEMENT OF CONDENSER AND CONNECTIONS

The air pump should always draw water from the cold well and may if desired, discharge back into the source of supply, as the water in passing through the pump, is not materially heated. If the supply of water is ample, the air pump may discharge into the hot well.

There will be installations in which it will be impracticable to locate the cold well in close proximity to the condenser. As stated before, it is usually desirable to allow the air pump to discharge into the cold well, as in normal operation the air pump uses about 15% as much water as the condenser proper,

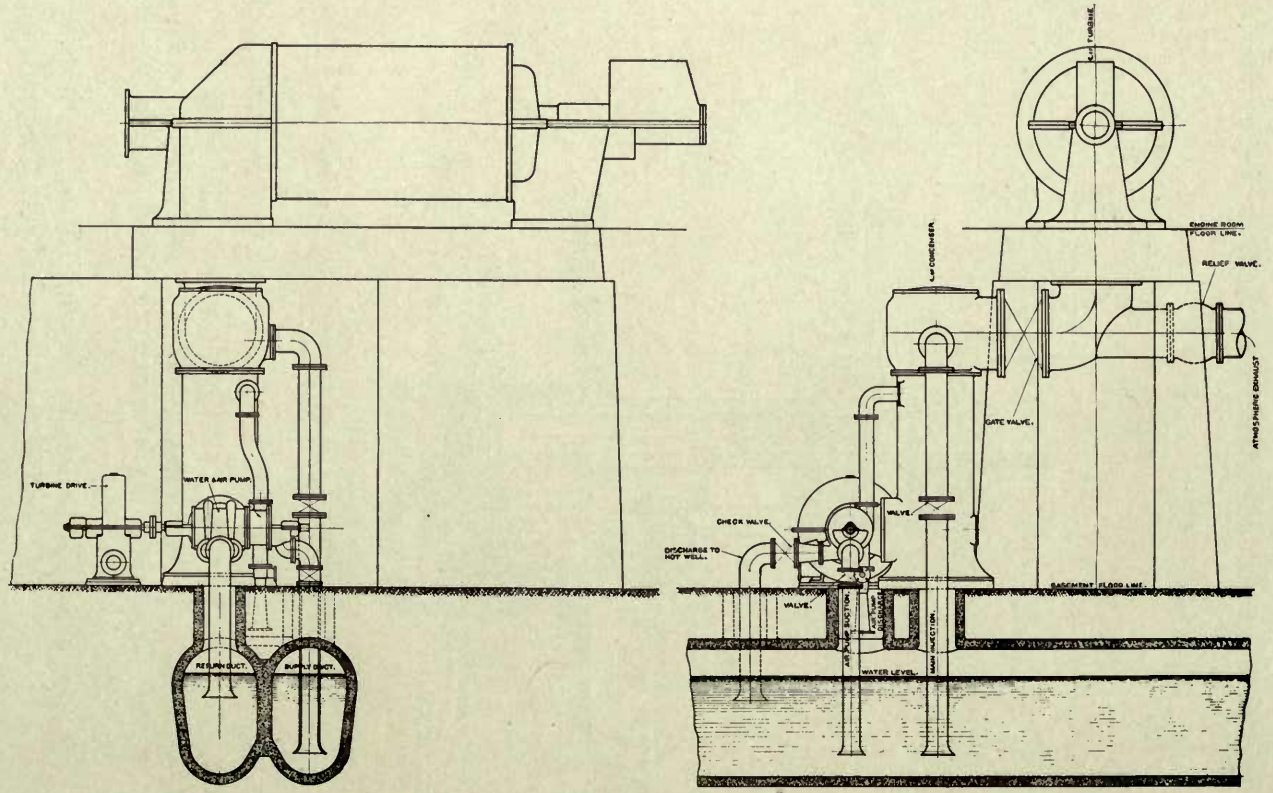


Fig. 6

TYPICAL SCHEME OF INSTALLATION

and in a single passage through the air pump, the temperature of the water is not raised more than ½ degree Fahrenheit. In some cases the cold well is of necessity located higher than the base of the condenser, so that the air pump will have to discharge against a head. It is possible to have this head as much as 12 feet. This should not be exceeded unless the air pump is especially constructed to meet the specific conditions. Such an arrangement is illustrated in Fig. 7.

In case it is not feasible to carry the air pump discharge to either the hot or cold well, a pit adjacent to the condenser may be utilized for the air pump. The air pump will draw water from and will discharge back into this pit. While, as stated above, the water in a single pass through the air pump is not heated more than ½ degree Fahrenheit, when used over and over its temperature will gradually rise to a point where the air pump will not be able to operate with maximum efficiency. Therefore, if the air pump draws its water from and discharges it back into the same pit it is necessary to bleed a small amount of cold make-up water into the pit to keep the temperature down. If water under pressure is not available, it may be taken from the main injection line (see Fig. 8). The air pump suction valve may be throttled to such an extent that the vacuum between it and the pump will be sufficient to draw water over from the main injection. This of course, will tend to gradually fill the pit, so that an overflow should be provided at such a level that the air pump discharge cannot be submerged.

In case it is not possible to drain the pit, a connection controlled by a float valve can be made between the pit and the condenser body. The condenser will then draw out just the same quantity of water that is let in by the make-up line. This arrangement is also illustrated in Fig. 8.

For this last described arrangement adjustments will have to be made with the valves in the air pump suction line, and the valve in the air pump make-up line. The valve in the make-up line should be opened wide, then a position of the valve in the air pump suction must be found that will cause just enough water to be drawn over through the make-up line to keep the temperature of the water in the pit not more

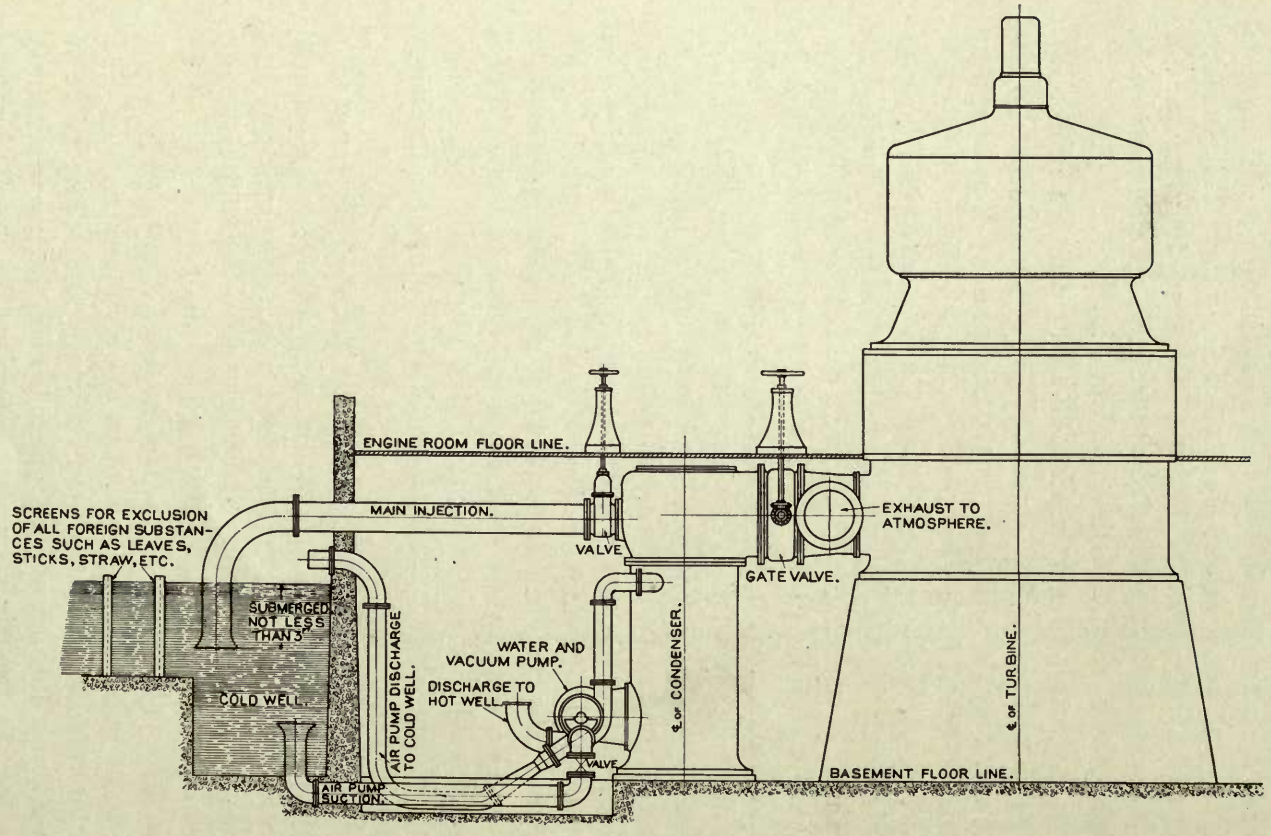


Fig. 7

AIR PUMP DISCHARGING AT AN ELEVATION

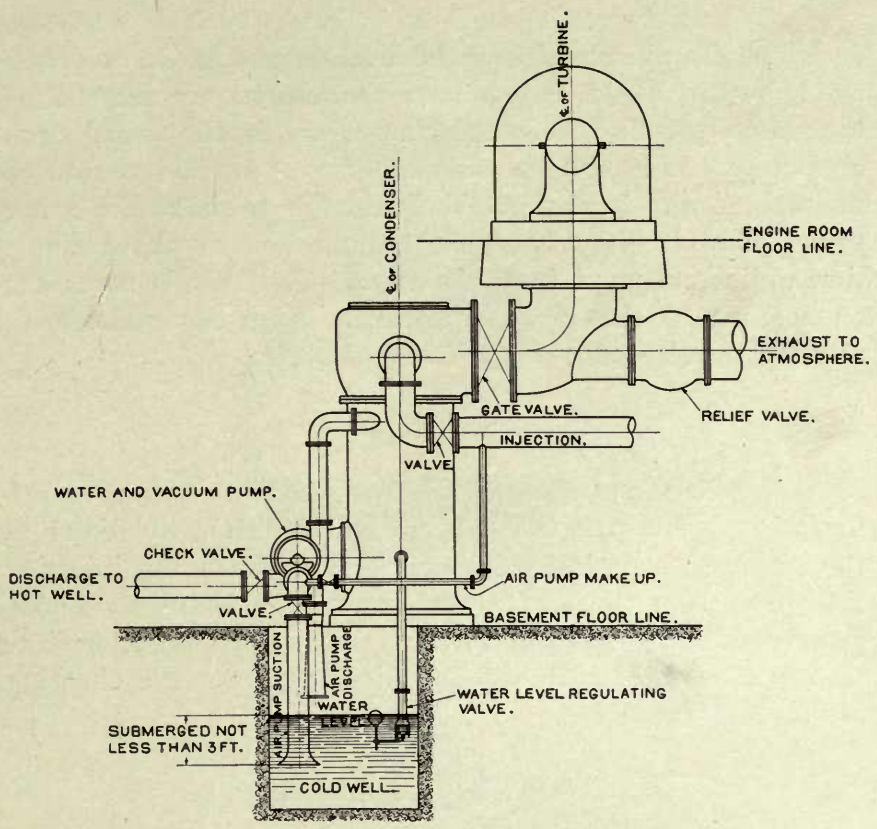


Fig. 8

SPECIAL ARRANGEMENT OF INDEPENDENT WELL FOR AIR PUMP

than 2 degrees higher than that of the main injection water. Should the pit show a tendency to overflow, the valve in the make-up line should be slightly closed.

In cases where an air pump pit is used, the pit must be ample in size. It must be remembered that the water coming from the air pump is heavily charged with air, as all the air pumped out of the condenser is mixed with the water discharged from the air pump diffuser.

The suction intake to the air pump should be not less than ten feet away from the diffuser discharge and be submerged beneath the water surface by at least four feet. The pit should be so proportioned that in case the whole cubical contents of condenser were drained into it, it would not overflow.

Where the condenser is to operate with salt water we do not advise the adoption of the arrangement above described and shown in Fig. 8, unless extra precautions are resorted to to separate the air held in solution in water discharged from air pump. At least 8 feet submergence of suction should be maintained and baffles placed in the pit to make the water travel in a circuitous path so that the air may have ample time to liberate itself from the water. All this is necessary on account of the persistence with which air remains in solution in salt water.

Strainers

While the condensers are designed with passages sufficiently large to pass the foreign matter ordinarily found in the water, it is desirable to have a strainer in the injection line to prevent the entrance of such large bodies as sticks, stones, etc. A grating or strainer in the injection line having about $\frac{3}{8}$" mesh will effectively prevent the clogging of the condenser parts.

Care and Attendance

In general, the Leblanc condenser needs less attention than any other type of condenser designed for high vacuum service. All movement is rotary without rubbing parts, so that lubrication is necessary for the bearings only. There are no valves in either the air pump or the water pump, so that the usual condenser troubles resulting in loss of vacuum due to leaky valves are entirely eliminated. The inherent efficiency of the Leblanc Condenser will not fall off after long periods of operation as is the case with condenser systems where reciprocating air pumps are used, reciprocating pumps being subject to losses due to leaking valves, worn piston rings, etc.

After reading the above statements and referring to previous pages showing the general construction of the condenser, it is readily seen that the care of the mechanical operation is limited to seeing that the glands are kept tight and sealed with water and that the bearings are properly

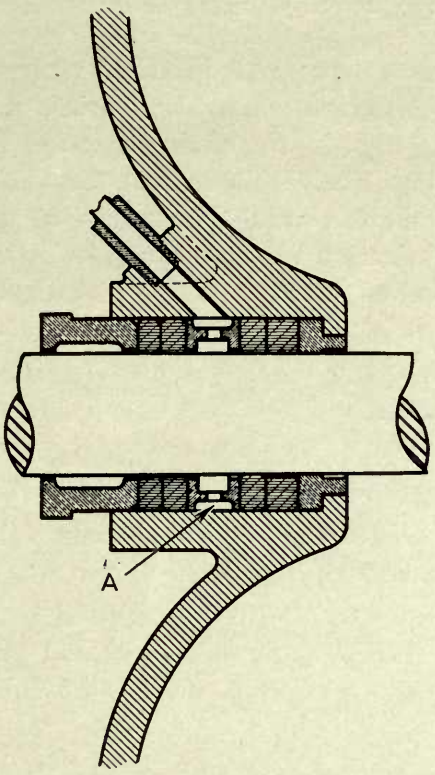


Fig. 9

SECTION THROUGH WATER-SEALED GLAND

lubricated. A sectional cut of the gland is shown on page 15, Fig. 9. It is essential that these glands be water sealed through the tapped connection shown. In repacking, care must be taken that the brass distance piece "A" be kept practically central in the stuffing box, so that it is in proper position to distribute the sealing water all around the shaft. Clear water only should be used in this seal as with dirty water sediment would be deposited in the packing, and this gritty deposit will in time cut the shaft.

The bearings are ring oiled, there being two oil rings to each bearing. Sufficient oil should be poured into the bearings to insure copious lubrication and the supply should be renewed when required. In continuous station operation of any high duty vacuum apparatus air leaks should be eliminated to the utmost degree possible. Methods of detect-

ing leaks and their probable location will be covered in later pages.

In case the condenser is installed where the water level of the source of injection constantly varies, it is desirable to place a vacuum gauge in the main injection line and in the air pump suction line. These gauges should be located between the condenser and the valves in their respective lines, and both injection valves should be adjusted for variation in water level as described on pages 20 and 21.

Starting the Condenser

Case 1. Where there is an exhaust valve between the turbine or engine and the condenser.

Case 2. When there is no exhaust valve between engine or turbine and the condenser and where there is no source of water under pressure for priming the condenser.

Case 3. Where there is no exhaust valve, but where there is a supply of water under pressure for starting condenser.

Case 1

Close the exhaust valve between the turbine or engine and condenser, open the main injection valve to the condenser a few turns; open the air pump suction valve wide; get pumps up to speed and in case of a turbine drive make sure that before admitting steam to small turbine driving pumps that all drains on the steam line have been opened and the lines drained; turn on the water seal to the condenser pump shaft glands, and open the steam primer. The vacuum created by the primer will immediately bring water to the air pump and the primer should be opened wide and kept so for half a minute even though the air pump has gotten its water. This will augment the vacuum and get the whole installation under a high vacuum in a very short space of time. In fact, on the condenser test floor this vacuum will, in less than two and one-half minutes, be within half an inch of the highest vacuum obtainable.

In cases where there are motors or generators or high tension wires above the air pump discharge, it will, of course, be unwise to keep this priming line open any longer than is just necessary to get the water to the air pump, as the free steam would rise and dampen the electrical apparatus. After the air pump has once gotten its water it will easily pull the vacuum up the rest of the way but not quite as rapidly as with method of procedure described in the paragraph next preceding.

When the vacuum has risen to about 25" or 26" the main injection valve which was only slightly opened should be opened until the condenser is circulating the proper amount of water. The exhaust valve can now be opened and the main unit which has been warming up or running non-condensing can exhaust into the condenser. The atmospheric relief valve, of course, should be closed and its water seal turned on.

Case 2

There are some installations in which no valve is provided between the steam engine or turbine and the condenser.

In such cases the condenser cannot be started when the main engine or turbine is in operation, since the condenser would be filled with exhaust steam and water must be drawn into the condenser to condense this steam before vacuum can be created. But the water will not be drawn into the condenser until the vacuum exists, so that it is manifestly impossible to start when the main unit is pouring exhaust steam into the condenser.

It will therefore be readily seen that the main unit (turbine or engine) must be shut down when the condenser is being started and furthermore that the stuffing boxes or glands on the shafts or piston rods must be tight against air leakage when the machine is at rest. That class of turbines which use centrifugal water sealed glands which are tight only when running, are not well adapted to this kind of installation.

In a general way it is a disadvantageous arrangement, since if for any reason the vacuum is lost, the engine or turbine must be shut down before the condenser can again be put

in operation. This objection, of course, is not applicable in the case of low pressure turbines as they are inoperative any way when the vacuum is lost, and they are nearly always equipped with glands that are air tight when the turbine is at rest.

With the engine or low pressure turbine not operating, the procedure of starting will be the same as for Case 1.

Case 3

When there is no exhaust valve but where there is a supply of water uuder pressure for starting the condenser.

In this case the condenser may be set in operation while the main unit is running non-condensing, either with or without load.

With no gate valve between the main unit and the condenser, and the main unit operating non-condensing, the condenser would be full of steam, as described in Case 2. However with a supply of water under pressure to enter the condenser and condense the steam a vacuum is quickly created. With the vacuum once created, the condenser will draw its own water and can go into regular operation.

The procedure of starting would be as follows:—

Bring the pump up to speed; turn on the water seal to shaft glands; open wide the air pump injection water valve; adjust atmospheric relief valve for running condensing; close condenser injection valve and open the water pressure line that is connected to the main injection between the condenser and injection valve. The water under pressure will immediately create a partial vacuum which may be sufficient to prime the air pump, and if not, open the steam primer in the regular way, after the injection is opened.

In case the air pump discharges into a pit and the end of the air pump diffuser is not submerged, it will be necessary to open the steam primer before opening the injection as otherwise air would immediately travel back up the air pipe and no initial vacuum could be established by the injection water.

The injection water which is under pressure is usually supplied for a few minutes only when starting the condenser,

for after the vacuum is once established the main injection line may be opened and the pressure line closed and the condenser will draw its own water. The usual custom in installations of this nature is either to connect a water pressure line in the injection line between the condenser and the main in-

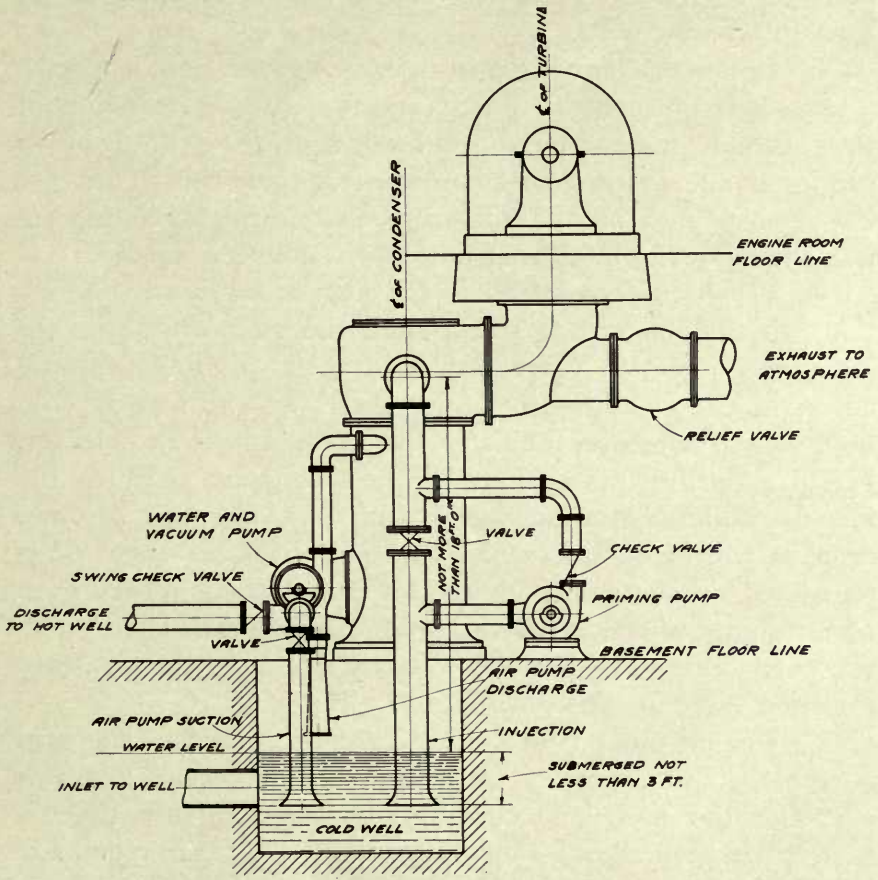


Fig. 10

SPECIAL ARRANGEMENT WITHOUT EXHAUST VALVE BETWEEN CONDENSER AND TURBINE. A PRIMING PUMP IS USED FOR STARTING

jection valve, or have an auxiliary priming pump which bypasses the injection valve (see Fig. 10.) In either case, the main valve is closed while starting up until the vacuum is established and then opened before the pressure line is closed.

The Air Pump

When the vacuum has been obtained, the air pump suction may be throttled down. It should be closed to such a point that the needle on the air pump suction gauge stands at the red mark on the dial. This dial is marked at the proper place as indicated by the test of the condenser made at our East Pittsburg Shops.

In plants where there is an excessive air leak, it may be necessary to open the air pump injection further to maintain the maximum vacuum, giving a lower reading on the air pump suction gauge. If it should be necessary to do this in order to keep the vacuum produced by condenser to the maximum figure, the following method of procedure should be adopted:

When the condenser is running under normal conditions, that is, condensing steam from the main unit, open the air pump injection valve wide and then gradually throttle down, in the meantime carefully observing the mercury column which, of course, indicates the vacuum in the condenser. When throttling down, there will be some point at which the mercury column showing vacuum in condenser will begin to drop, say for case of discussion that this happens when 18" is registered on the gauge on the air pump suction, then open up air pump injection till this gauge registers about 2" less, viz. 16". This should be the ordinary setting of the air pump injection valve for this installation.

The air pump is designed to handle twice the amount of air that should naturally come in with the injection, but as a portion of the air is held entrained and discharged to the hot well, it has been shown by test that the air pump is capable of handling two and a half times the amount of air liberated from the injection water. This means that the air pump is quite liberally designed and if the proper vacuum is not maintained a disproportionably large amount of air is probably leaking into the system.

The power taken by the air pump is proportional to the amount of water allowed to pass through it. It is, therefore, desirable to reduce the air leakage as much as possible, thereby reducing the amount of water required by air pump and, consequently, reducing the horse power required for its operation.

Regulation of Injection Water

When the amount of injection water available is unlimited, the injection valve should be opened as wide as possible without flooding the condenser or causing the vacuum breaker to open.

This, of course, assumes that care will be taken not to overload the motor or turbine driving the pumps, also that the injection water is at a moderate temperature for with very cold water, say below 40°, the increase in vacuum will be small compared with the increase of power required to handle the water in the condenser.

The more water put through the condenser the better, of course, will be the vacuum. This extra vacuum gives the main unit from which the condenser is condensing the steam, greater power and in the case of a turbine where a high vacuum is extremely desirable. the power delivered at the switch board increases more rapidly than the power required by the condenser to discharge the additional amount of water. This last statement is not strictly correct as applied to a reciprocating engine, as in this type of engine, any in crease of vacuum over 26", means a very small increase of power.

Condenser Inspection

The condenser has been carefully designed to facilitate quick and thorough inspection. A manhole at the top allows easy access to the injection nozzles. The nozzles (Fig. 1 marked "B") are on a plate which is held in position by three slip bolts and a hinge bolt. An eye-bolt, not shown in the figure, is placed diametrically opposite the hinge bolt. By putting a piece of rope through the eye bolt and fastening it to one of the nozzles the plate can be lowered for inspection to see if any foreign matter is in the nozzles. These nozzles should always be inspected a few days after the condenser is set in operation, as pieces of gaskets, sticks of wood, etc., are apt to be left in the injection line when installing and are deposited on the nozzles by the flow of water.

The discharge pump has a sight hole on the volute and the air pump has two sight holes, one on the top to see if the

blades are clear and one on the side for inspection of the water distributer which is on the inside of the air pump wheel. By opening these sight holes and turning the shaft by hand from the coupling end, a thorough inspection can be made. A large manhole on the back of the condenser body allows the interior of the discharge pump to be inspected.

Location of Gauges and Method of Taking Condenser Readings

In taking readings to determine if the condenser performance is satisfactory, care must be taken that gauges and thermometers are in the proper place.

The main injection gauge should be placed between the condenser and the injection valve. The gauge should be placed as close to the condenser as practicable.

The air pump suction gauge should be placed between the air pump suction valve and the air pump or on the air pump body where a tap is provided for it.

The discharge pressure gauge should be placed as close to the condenser discharge pump as possible and to get accurate readings this guage should not read to more than 30 pounds.

The vacuum in the condenser should not be measured by a gauge as it is not sufficiently reliable or sensitive for accurate work. A mercury column should always be used and should be tapped into the condenser head.

Should a vacuum gauge be placed on the condenser care should be taken to locate it above the point at which it is tapped into the condenser, so that all condensation in the gauge pipe will drain back to the condenser.

The thermometer for measuring the temperature of the injection water should be placed in the injection line.

The thermometer for measuring the temperature of the discharge water may be placed in the discharge line or in the pump body where a pipe tap is provided for it.

The thermometer for measuring the temperature of the exhaust steam should be placed on the top of the inlet chamber of the condenser diametrically opposite the exhaust steam en-

trance, so that no errors will be introduced by heat being conducted from the turbine or engine cylinder.

The barometer reading should preferably be taken in the engine room, but if this is not practicable, a reading should be taken from the nearest barometer that is available. As climatic conditions vary so much, a reading from a barometer ten miles from the power plant would be of doubtful value. The elevation must also be taken into account as a difference of altitude of 100 ft. makes a difference of one-tenth of an inch of mercury in the pressure of the atmosphere, consequently if the barometer reading were taken on top of a high building, it would have to be corrected to the engine room level, at the rate of one-tenth inch per hundred feet elevation.

In taking readings on a condenser, there are three that should, if possible, be taken simultaneously, particularly in the case of a fluctuating load, such as is common in electric railway service. These readings are:

1. Vacuum by mercury column.
2. Temperature of exhaust steam.
3. Temperature of discharge water.

Fig 11 shows a log sheet for a condenser test and if a test is run and the data sent to us we are always glad to analyze it, and give customers the benefit of our suggestions.

In testing an installation, make one test on the condenser alone, that is, with the main steam inlet and the main injection valve closed; simply run the air pump. Just before taking readings, open the main injection valve three or four turns to throw out all of the hot water that may be in the condenser, close the main injection slowly, wait about two or three minutes, then take the reading by mercury column, and the temperature of the air pump injection water. From these readings together with the barometer reading you can, by referring to the table of temperatures and pressures for water vapor herewith, easily determine whether or not the condenser in itself is working properly.

Take the vapor tension or absolute pressure in inches of mercury corresponding to the temperature of the water in the condenser and add this to the vacuum in the condenser, measured in inches of mercury. If the condenser is in good condition the sum should equal the barometer reading.

Form [illegible] (Litho. No. [illegible]) 10M 12-09

The Westinghouse Machine Co.

CONDENSER PERFORMANCE

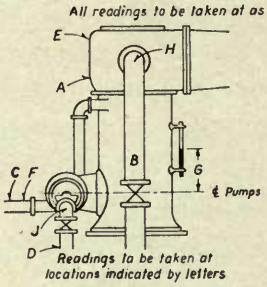
Customer_____

City & State_____ Size Condenser_____

Serial No._____

Date	Time					
Load in K.W. on Main Engine or Turbine						
Vacuum at Condenser by Mercury Column	(A)					
Barometer						
Temperature of Injection Water °F.	(B)					
Temperature of Discharge Water °F	(C)					
Temperature of Air Pump Injection Water °F	(D)					
Temperature of Steam in Exhaust line from Engine or Turbine to Condenser	(E)					
Back Pressure, lbs. per sq. in. on Condenser Discharge Pump	(F)					
Height of Water in Condenser Body above center line of Pumps	(G)					
Vacuum at Condenser Injection Inlet	(H)					
Vacuum at Air Pump Injection Inlet	(J)					
Speed of Pumps - R.P.M.						
Steam Pressure - Lbs. Gauge						

All readings to be taken at as nearly the same time as possible, particularly E - A and C in the order named.



Remarks:_____

_____

_____

_____

_____

_____

Signature_____

Fig. 11

LOG SHEET FOR CONDENSER TESTS

An explanation of the table is as follows:

Water boils under atmospheric pressure (30" barometer) at 212° F. As the pressure is reduced, the temperature of the boiling point is likewise reduced. Therefore, knowing the temperature of water in condenser we can easily get the absolute pressure in inches of mercury at which it would boil. So when the air pump has evacuated the air down to the boiling pressure of the water, no lower pressure can be gotten as the water goes off into steam. Therefore, if we take the vacuum in the condenser in inches of mercury, plus the pressure due to the temperature of the water in the condenser the sum should equal the barometer reading.

For example:

Tem. of water in condenser=73°.

Vac. by mercury column=28.72.

73° water corresponds to 0.812 inches of mercury. (See table page 26).

0.812+28.72=29.532 which should be equal to the barometer reading.

If the barometer is lower than 29.532" there has been some error in the readings taken. If the barometer is higher than 29.532" there is an air leak in the condenser.

AIR LEAKS

How to Find Them and How to Remedy Them

If air leakage is suspected in a condenser installation, it will, of course, only be necessary to look for it in parts of the system subject to vacuum. Referring to Fig. 12, the parts subjected to vacuum are shaded.

Water Injection Line

Run the condenser with the air pump only; that is, with main exhaust and injection valves closed, and note the vacuum obtained. Then open the injection valve and after running a few minutes if the vacuum has dropped more than 3-10 or 4-10 of an inch, then there is a leak in the injection line. A drop of 3-10 to 4-10 of an inch is to be expected as there is usually 2%

Temp. of Water Deg. Fahr.	Absolute Press. Inches of Mercury	Temp. of Water Deg. Fahr.	Absolute Press. Inches of Mercury	Temp. of Water Deg. Fahr.	Absolute Press. Inches of Mercury	Temp. of Water Deg. Fahr.	Absolute Press. Inches of Mercury	Temp. of Water Deg. Fahr.	Absolute Press. Inches of Mercury
30	.....	50	0.361	70	0.734	90	1.411	110	2.577
31	.....	51	0.375	71	0.759	91	1.456	111	2.655
32	0.181	52	0.389	72	0.785	92	1.502	112	2.733
33	0.189	53	0.403	73	0.812	93	1.548	113	2.810
34	0.196	54	0.418	74	0.939	94	1.598	114	2.892
35	0.204	55	0.434	75	0.868	95	1.648	115	2.977
36	0.212	56	0.449	76	0.897	96	1.699	116	3.061
37	0.221	57	0.466	77	0.928	97	1.751	117	3.150
38	0.229	58	0.483	78	0.959	98	1.807	118	3.240
39	0.238	59	0.501	79	0.991	99	1.862	119	3.330
40	0.248	60	0.519	80	1.024	100	1.918	120	3.427
41	0.257	61	0.537	81	1.058	101	1.978	121	3.523
42	0.267	62	0.556	82	1.093	102	2.046	122	3.624
43	0.278	63	0.576	83	1.129	103	2.099	123	3.724
44	0.289	64	0.596	84	1.166	104	2.162	124	3.827
45	0.300	65	0.617	85	1.203	105	2.227	125	3.933
46	0.311	66	0.640	86	1.243	106	2.294	126	4 043
47	0.323	67	0.662	87	1.283	107	2.363	127	4.153
48	0.335	68	0.685	88	1.324	108	2.433	128	4.266
49	0.348	69	0.709	89	1.367	109	2.506	129	4.387

TABLE OF TEMPERATURES AND PRESSURES FOR WATER VAPOR

of air by volume in any water and this air expands when it has entered the condenser and causes a drop in the vacuum.

There are usually three sources of leakage: the valve stem packing, the line itself, or at the cold well, due to insufficient submergence of the injection line.

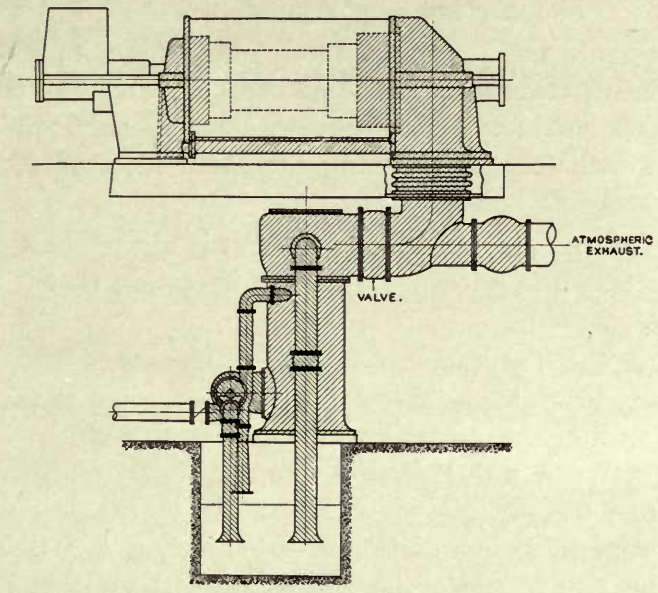


Fig. 12

DIAGRAM SHOWING PORTIONS OF TURBINE AND CONDENSER UNDER VACUUM

To test the injection line, tap in a vacuum gauge close to the injection valve on the side towards the cold well. With the condenser drawing about its rated amount of water, take a reading and then close the injection valve and take readings at intervals of several minutes. The difference between the readings taken directly before and after closing the valve will indicate the friction head in the water line in feet, as one inch of vacuum corresponds to about one foot head of water. Make two tests, one test with the condenser running and the other with the condenser stopped directly after closing the injection valve, as the main injection valve may leak and a comparison of the two readings will show this.

If the injection line is tight then there may still be a large amount of air admitted to the condenser by too small a

submergence of the injection pipe in the cold well. It should always be submerged at least four feet and preferably more, otherwise eddys or whirlpools will form through which air will pass into the injection pipe. This can be stopped temporarily by building a floating platform around the pipe which will break up the whirlpool, but the proper remedy would be to increase the submergence.

Should the air pump suction line take its water from the main injection it would be necessary in testing the tightness of the main injection line to close the air pump water valve immediately after closing the main injection valve and then proceed as before.

When installing a condenser, it is always best to leave the injection line uncovered until it is certain that it does not leak at any point.

Should the vacuum in the condenser surge, that is repeatedly drop two or three inches and recover itself, it is an indication that the condenser first gets a gulp of air and then a gulp of water although the line may be perfectly air tight. It is occasioned by air pockets forming in the injection line due to uneven laying of the pipe. Thus, if the line is laid with "ups and downs," a pocket of air will form at the crest of each rise due to natural separation of air and water when under a vacuum. These pockets of air going to the condenser spasmodically, cause the surging, and sometimes even cause the condenser to lose its vacuum entirely. This can be remedied by connecting a small pipe, say about one inch, into the injection line at the highest point and leading it to the condenser body, inserting a valve close to the condenser. This one inch line will take off the air as it collects and stop the surging.

Condenser

Proceed as described under "Location of Condenser Gauges and Method of Taking Condenser Readings" on pages 23 to 25. In addition, fill up the exhaust pipe to condenser with water in order to effectually seal and stop any air leak through the main exhaust valve. Also make sure that there is no air leak through the exhaust valve stem packing.

Atmospheric Relief Valve

This valve may not be properly sealed with water and it may not seat correctly. This can readily be determined by running the main unit, preferably under no load, throw in the condenser and then taking off the cover or cap on the relief valve, see if it is in operative condition. Also see that the valve stem, which in the case of a horizontal valve, comes from the vacuum side, does not leak around the gland or stuffing box.

Exhaust Pipe

In some cases the exhaust pipe, which is of cast iron, has blow holes, sand holes or other imperfections. The best way to locate them is to close the main exhaust valve and fill the exhaust line with water and any hole will quickly show up. Small holes can be easily stopped up with asphaltum paint applied while the line is under vacuum. Large holes should be drilled out and plugged.

At the lowest point in the exhaust pipe there are usually attached two check valves in series that permit any water that accumulates in the line while the engine is standing idle or running non-condensing, to drain out. There may be foreign matter in these valves or they may not close properly. This is easily determined by breaking the joint outside of the valves and screwing on an elbow or some sort of riser so that the valves may be water sealed. Fill the riser with water and with the condenser under vacuum observe if the water disappears. Of course, if it disappears there is a leak and a simple way to stop it is to put about a six inch riser outside of the valves and into the bottom of this riser lead the drain from the atmospheric relief valve seal, and from the top of this same riser lead off the overflow. The drain from the atmospheric relief will thereby keep the check valves sealed.

Air in the Steam

This is often occasioned by the boiler plant not having a good feed pump. In the case of a reciprocating feed pump the engineer in charge may not keep the pump glands well

packed. It is particularly noticeable when the pump will go a full stroke quickly and is easily seen to be drawing in air rather than water. In a well designed plant the feed water heater is usually above the pumps so that the water flows by gravity and the tendency to draw in air is consequently diminished. After the air is drawn in it is compressed and forms an emulsion with the water and is in that state forced over into the boiler, and eventually to the condenser. This, of course, impairs the vacuum in the condenser and it cannot be impressed too strongly on the operating engineer that the vacuum depends a great deal on the way he keeps his boiler plant up to date and that a few cents spent in packing will repay him in dollars in power delivered from the main unit.

Various Points of Leak

The expansion joint may be cracked.

With a reciprocating engine the piston rod packing may be in bad condition.

The vacuum breaker on the condenser may have sediment under the seat. The valve should be tight enough to hold water and if not, grind it in with a little emery.

If the main unit is a turbine, look for leaks in the intermediate and low pressure equilibrium pipe; the gland drain where it goes inside of the turbine exhaust nozzle; this latter point can be examined by breaking the drain where it leaves the exhaust nozzle, plugging it and filling the line with water up to the turbine gland; if the water disappears there is a bad connection inside of the exhaust.

The turbine glands should be sealed with the coldest water obtainable, for if the gland water is warmer than the temperature of the vacuum, the water will go off into steam and will not effectively seal the glands.

A rough determination of the amount of air leakage in the turbine and exhaust pipe as a whole, can be made in the following manner:

Have the turbine running under no load, the condenser condensing the steam from it and then close the steam valve to the turbine. As the turbine is up to speed and run-

ning in a vacuum it will maintain its speed and seal the glands for at least five or more minutes. Now by closing off the main injection the condenser should be able to maintain as high a vacuum running this way as if the condenser were running by itself, that is, with the main exhaust valve closed.

In General

The exhaust piping is, of course, installed in a cool condition and the gaskets become soft when the piping is heated. Therefore, it is best to run the main unit non-condensing and tighten up all joints well while hot. Also the atmospheric relief valve will put a slight back pressure on the exhaust line and any bad leaks will show up.

After tightening joints, paint the whole joint with asphaltum paint. In painting a joint, paint the whole flange including the bolts and nuts. It is not sufficient to paint just the outside of the flange alone, as air may leak under the head or nut of the bolt and travel down the bolt hole as all bolts have about $\frac{1}{8}$" clearance in the holes.

The best method of locating a leak is to put the part being tested under a water pressure and look for water drips. Another method is to get the line under a vacuum and test joints with a candle flame. The water test is preferable as it will show up not only leaky joints but also blow holes and sand holes in the pipe itself, which one would not know where to look for in applying the candle flame test.

The Westinghouse Machine Co.

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East Pittsburg, Pa.

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